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FAN BLADE DEVELOPMENT

GARD FINAL REPORT A1-48

September, 1982

By

John M. Buday

For

Donald A. Bettge
FEDERAL EMERGENCY MANAGEMENT AGENCY
Washington, D.C. 20472

under Contract No. EMW-C-0600
FEMA Work Unit 1423G

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Fifteen fan blades of the optimum design were constructed for FEMA inspection and distribution.

Preliminary specifications were generated for the fan blade assembly. In addition, production cost estimates based on a procurement of 100,000 units were formulated for FEMA budgetary purposes.

FOREWORD

This Final Report was prepared by GARD, INC., Niles, Illinois for the Federal Emergency Management Agency under Contract No. EMW-C-0600. The effort performed under this program was monitored by Mr. Donald A. Bettge of Civil Defense Division, FEMA.

The report covers the work performed on the contract during the period of 1 September 1981 to 30 June 1982. It describes the value analysis study, fabrication and testing of a cost-effective fan blade for use on Pedal Ventilator Kits (PVK) in Civil Defense shelters.

The author wishes to thank Mr. R. J. Klima and Dr. L. B. Holmes for their many contributions to the performance of the above effort, and Mr. H. M. Sitko for conducting the fan validation tests. Thanks are also due to Mr. Bettge for his valuable technical inputs during the course of the subject program.

Respectfully submitted,

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ABSTRACT

The objective of this program was to develop an improved fan blade that could be utilized in place of the current steel fan blade on the Pedal Ventilator Kit (PVK).

The goals of the program were to reduce both the unit cost and weight of the fan while maintaining its effectiveness and reliability.

A value analysis study was conducted on the fan blade to determine material/design revisions that offered potential manufacturing economies. Based on the conclusions of the study, two designs were selected for fabrication. The two fans were constructed and tested. As a result of the performance testing, one fan blade emerged as the optimum design.

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Section 1

BACKGROUND

The one-operator Pedal Ventilator Kit (PVK) was originally developed in 1969[1]* to provide ventilation of designated fallout shelters without requiring hookup to any external source of power, i.e., electrical, hydraulic or pneumatic. It was designed to be portable, requiring little or no assembly within the shelter, and capable of operation by a single individual.

In subsequent years the PVK and other types of ventilator kits were evaluated for cost effectiveness, and engineering studies were conducted to determine potential engineering economies.[2] Based on these studies, fabrication drawings, specifications, and deployment instructions were updated to reflect modifications determined to be cost effective. Prototypes, based on the updated documentation, were built and tested to ascertain that performance and reliability were not compromised.

GARD recently completed a program for FEMA under Contract No. DCPA01-79-C-0234, wherein alternate materials that could be used in the construction of a PVK were investigated for purposes of reducing the PVK unit cost in a large-scale procurement.[3] The largest and heaviest component, the support frame, received major consideration and a completely redesigned unit, injection molded from glass fiber reinforced polypropylene, was developed. In addition the fan shroud and drive sprocket were also replaced by plastic counterparts. These changes reduced the weight of the PVK from 72 lbs to 53 lbs. More important, perhaps, they reduced the estimated production cost by 39%.

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* Superscripts refer to Section 6, References.

When the additional savings achieved by the lower shipping weight was considered, the total cost reduction was greater than 40 percent. The alternate material PVK prototype is shown in Figure 1.1.

During the above program several additional PVK components were evaluated for glass reinforced plastic construction. One of these components was the PVK fan. The current fan has a unit cost of $15.54 each in large scale production quantities and weighs 9.9 pounds. It was recommended that a replacement plastic fan be developed which would significantly reduce both cost and weight. Further, the "alternate material" PVK at this point consisted of approximately 85% plastic components and the fan was the largest remaining nonplastic part.

During the program a handmade fan prototype of ABS plastic was constructed and tested. It was concluded from the test results that a fan constructed of glass filled polypropylene could be a viable candidate for PVK implementation. This report describes the research and testing performed in the fan blade development.

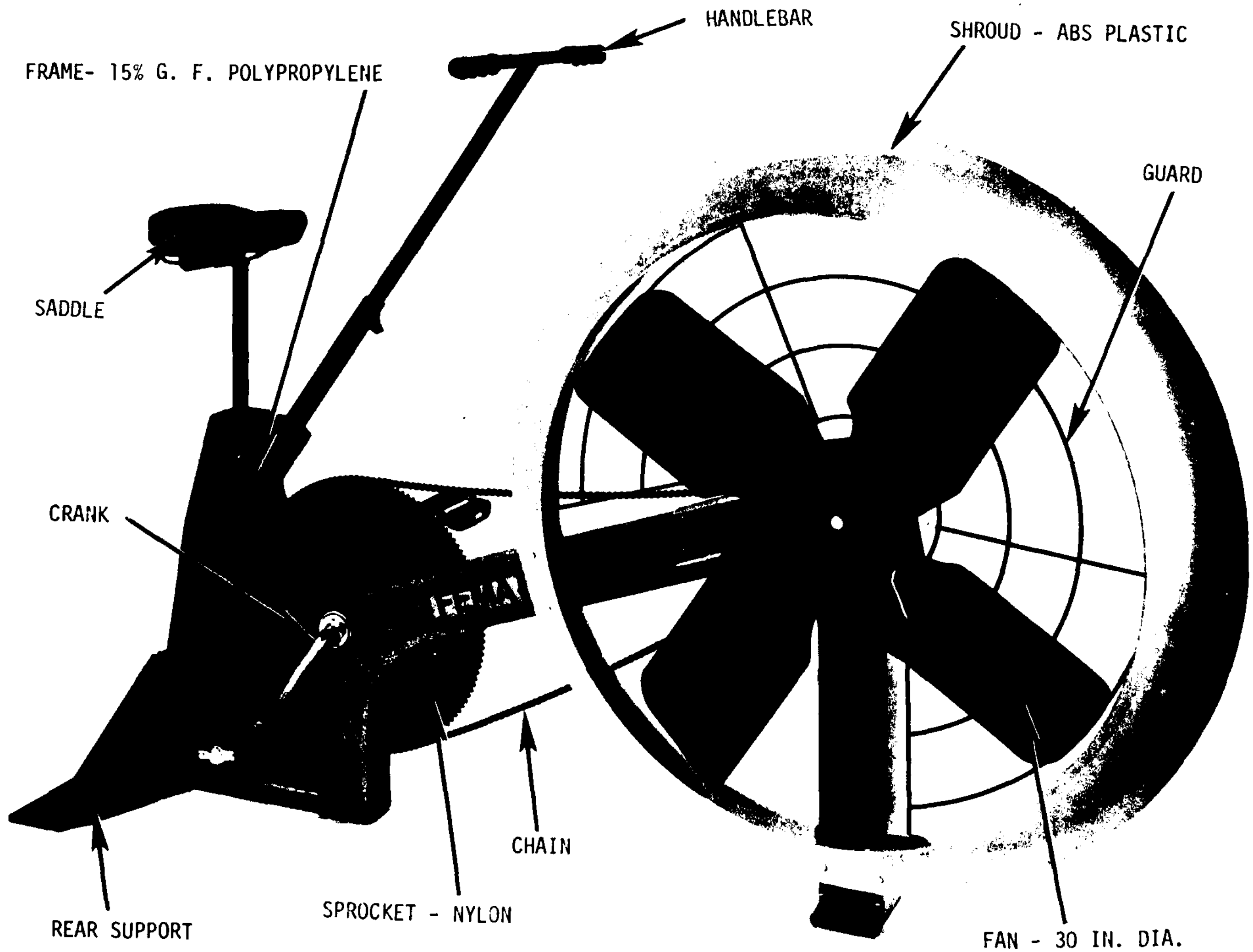


Figure 1.1 ALTERNATE MATERIAL PVK PROTOTYPE

Section 2

FAN BLADE DEVELOPMENT

The present production PVK fan is comprised of four contoured (20° pitch) steel blades, 30 inch tip diameter, riveted to a steel spider hub. The fan is attached to the drive shaft with a taper lock collar.

The design of the present fan meets PVK requirements for an exceptionally efficient fan at low speeds (3200 CFM at 480 RPM), with moderate axial depth. This efficiency permits input horsepower as low as .10 HP, which is consistent for the manually powered PVK.

The fan described above was utilized as a basis for cost, weight, and performance comparison during the development of the new fan blade. The goals of the subject program were as follows.

- The fan blade shall be efficient at low speeds. At 480 RPM it shall have an air flow of 3200 CFM with input power of not more than 0.1 HP. Static pressure, brake horsepower and air flow shall be in accordance with or better than the qualification curves shown in the RFP Statement of Work.
- The fan shall have a diameter of 30.00 ± 0.05 inches, and shall fit into the PVK shroud developed under Contract No. DCPA01-79-C-0234, "Study of Alternate Material Pedal Ventilation Kits".
- Estimated mass production costs of the fan blade shall be $10.00 or less delivered to the Government.
- The gross weight of the fan should be reduced, if feasible.

- o Fifteen (15) prototype units shall be fabricated and delivered to the Government at the end of the contract. During the program one prototype fan blade shall be proof tested at high and low temperatures. It shall also be tested with the shroud for a continuous period of 2 weeks, 24 hours a day, or approved equivalent.

This section will describe the fan blade development from the value analysis study and design through the prototype fabrication.

2.1 Value Analysis Study

The program was initiated with a value analysis study to determine the optimum fan blade configuration. The analysis was applied to material, fabrication methods, weight, shape, and predicted performance. In addition, the parameters of 15 year storage life, ease of operation, impact resistance and reliability, were primary considerations in the development of the unit.

The basic goal of the study was to develop a PVK fan blade that can be fabricated and assembled for the minimum unit cost utilizing modern technology.

The study included a review of present fan technology, material, process search, and methods of assembly. These tasks are described in the following subsections.

2.1.1 Review Present Fan Technology

GARD has extensively researched the state-of-the-art of present fan technology both in steel and plastic construction during the performance of the alternate material PVK program for FEMA. This data was evaluated early in the subject program.

The potential of injection molding the entire fan of reinforced plastic was investigated. This would logically reduce the fabrication costs and weight of the unit. However, a technical canvas of existing plastic fan manufacturers revealed that present technology for one-piece molded fans is confined to a maximum of 20-inch tip diameter.

Discussions held with Emerson Electric and General Electric, two of the leading producers of commercial portable room air circulators, indicated the following problems are still prevalent in large (20-inch diameter or greater) molded fans.

- o The material thickness variation from hub to extreme tip diameter results in blade distortion upon removal (cooling) from mold.
- o Material flow problems exist in the molding process resulting in a high rejection rate.
- o Outer blade rigidity is reduced.

Based on the above data generated by corporations who devote extensive research funding towards new product development, it was concluded to design, fabricate tooling, and test a one-piece fan of 30-inch diameter would reduce the technical viability of the program. The cost of the prototype mold alone was considered prohibitive in conjunction with the projected success factors.

The most accepted method of construction for large diameter plastic fans is fabricating individual fan blades by either the thermal or injection molding process and fastening the blades mechanically to a composite material hub. This method of assembly will be presented in detail in Section 2.2 of this report.

2.1.2 Material and Process

The intent of this study was to develop the most efficient process utilizing materials compatible with the specific requirements of the fan blade, so as to produce the fan blades at the lowest unit cost. The parameters for both material and process analysis is a target run of 100,000 units or more over an estimated period of three years.

The following subsections describe the various methods and descriptions involving the selection of material and related process.

2.1.2.1 Material Study

The material search conducted for the Alternate Material PVK program recently concluded allowed GARD to significantly reduce the normal effort to perform this task. The material parameters for the PVK support frame were directly applicable to the fan blade requirements. The evaluation criteria included methods and ease of fabrication, optimum physical properties, and both raw material and fabrication costs.

The initial phases of the above search involved the wide spectrum of all possible candidate materials including plastics, steel, aluminum, composites, wood, zinc and reinforced hardboard. The results of the survey indicated that injection molded, reinforced plastics (FRP) were superior to other candidate materials in meeting both economic and performance standards for PVK structural elements. Since these parameters are related to the thin sectioned fan, the scope of the material survey for this program was expedited.

FRP are used in applications requiring both high mechanical strengths and lightweight requirements. This combination led directly to consideration of FRP as the principal alternate material candidate for the fan blade. Combining

fiberglass with plastics increases physical strength, stiffness, impact resistance and dimensional stability, while increasing use over wider temperature ranges. The specific gravity of FRP is roughly 20% that of steel and FRP products have strengths competitive with many structural materials. Depending on the amount of glass reinforcement used, and its particular geometry and arrangement in the resin mix, strengths can range from roughly half to several times those of structural steel. The plastics normally employed in FRP are the thermosetting materials, since highest strengths are obtained by combining the reinforcement properties of fiberglass with the cross-linked, three-dimensional gel structure of this type of plastic. However, due to the desirable properties of increased corrosion resistance demonstrated by the thermoplastic materials for PVK applications, structural part strength equivalencies can be obtained by optimizing fiberglass content in the basically straight chain polymeric thermoplastics. A further advantage to use thermoplastic resin bases is seen in fabrication by injection molding where thermoplastics do not undergo chemical curing as do the thermosets. Molding requirements for thermoplastics include heat applications only until the material softens and can be molded into the desired shape. After cooling, the substance hardens to the final product. Selection of thermoplastic resins thus improved the economics of molding press requirements which became significant in the cost effective determination of the PVK fan blade.

A large variety of injection moldable thermoplastic materials were surveyed for applicability as alternate PVK materials. The categories of parameters examined included physical and mechanical properties, fabrication technology, performance in service requirements and interrelated cost factors.

The major parameter examined for structural plastics was tensile strength. As a group, reinforced plastics equal and can at times exceed the strength of structural steels. From the multitude of available plastic hybrids, the glass fiber-reinforced injection molded types with the highest strength levels have been listed in order of decreasing strength as shown in Table 2.1.[4] As indicated in the chart, the strongest reinforced plastics are the polyamides (nylons) followed by the polycarbonates and the polypropylenes.

Based on the consensus of the above data, GARD selected 10 to 30% glass filled polypropylene for the fan blade material. The polypropylene has, in general, a lower water rate absorption than the nylons. Long storage life for the fan requires a non-hygroscopic material that will maintain the blade contour and dimensional stability. In addition, the raw material cost of polypropylene versus competitive plastics is illustrated in Table 2.2. The material cost of unfilled polypropylene, 30¢/lb, is low compared to other candidates, and is the same as cold rolled steel, which is the material used on the present fan blade.

Figure 2.3 illustrates the energy requirements per unit volumes for metals and plastics. It is noted that the energy per unit volume for polypropylene costs approximately one-half as much as steel, while the nylons cost about 75% of the cost of the same unit of steel.

The conclusions of the overall material study indicated that polypropylene (glass filled) was the most applicable material for the fan blade.

2.1.2.2 Process Study

The intent of the process study was to determine the most efficient fabrication process consistent with the specific requirements of the PVK fan blade. Since reinforced polypropylene had been forecasted as the primary candidate material for the PVK fan, the fabrication processes available were

TABLE 2.1

PROPERTIES OF INJECTION MOLDED GLASS FIBER REINFORCED (GFR) PLASTICS

GFR PLASTIC BASE	% of Glass	Tensile Strength (ksi)	Specific Gravity	Elastic Modulus (10^5 psi)	Impact Strength	Water Absorption (% in 24 Hr.)
6/10 Nylon	40	35	1.52	18.0	6.0	2.0
6/10 Nylon	20	13	1.17	5.0	1.2	0.2
6 Nylon	Range	13-30.5	1.17-1.18	2.0-5.10	.8-1.8	1.5
6/12 Nylon	Range	25-29	1.34-1.45	12-18.5	1.39-3.36	.13-.2
6/6 Nylon	30	19.5-28	1.34-1.37	10.0-12.5	1.7-2.1	.65-.75
Polypropylene	40 10	25 12	1.52 1.24	17.0 5.0	6.5 1.9	.20 .07
Polypropylene	40	14	1.22	8.0		
Polypropylene	30	13	1.12	8.5	1.5	.3
Polypropylene	20	7.0	.906	5.2	3.1	.01-.05
Polypropylene	10	6.5	.85	5.0	2.5	.01

TABLE 2.2 RAW MATERIAL COST COMPARISON

MATERIAL COST

Materials	Specific Gravity	¢/Lb.	¢/Cu. In.
DU PONT ENGINEERING PLASTICS			
Delrin® Acetal Resin	1.42	100	5.13
"Delrin" 500CL Acetal Resin	1.42	215	11.03
Zytel® 66 Nylon Resin	1.14	116	4.78
"Zytel" 612 Nylon Resin	1.07	206	7.97
"Zytel" Impact Modified	1.09	121	4.77
"Zytel" ST Super Tough	1.09	155	6.10
Lucite® T-1000 High Impact	1.15	79	3.28
OTHER DU PONT PLASTICS			
Alathon® Polyethylene Resin			
Low Density	0.914-0.940	31.5	1.04-1.07
High Density & Copolymers	0.941 & up	30.25	1.03-1.04
Du Pont EVA Copolymers	0.93-0.96	35-54.5	1.18-1.89
Surlyn® Ionomer Resin	0.94-0.96	68-76	2.31-2.64
"Lucite" Acrylic Resin	1.19	61	2.62
OTHER PLASTICS			
Polyester (thermoplastic)	1.31	98	4.64
Polystyrene—General Purpose	1.06	29-30	1.11-1.15
Polypropylene	0.905	30	0.98
Polyvinyl Chloride (Rigid)	1.20-1.37	27	1.17-1.34
Styrene Acrylonitrile Copolymer	1.07	45	1.74
ABS	1.04-1.06	48	1.80-1.84
Cellulose Acetate Butyrate	1.19	89	3.83
Modified Polyphenylene Oxide	1.09	113.5	4.47
Polycarbonate	1.20	113	4.90
Polysulfone	1.24	300	13.44
METALS			
Magnesium AZ—91B—ingot	1.81	101	6.60
Aluminum SAE-306			
(380-1% Zinc)—ingot	2.77	60-61.6	6.00-6.16
Aluminum SAE-309 (360)—ingot	2.64	60-60.5	5.72-5.77
Zinc SAE-903 ('Zamac' 3)—ingot	6.6	32.50	7.75
Brass-Yellow (#403)—ingot	8.5	62.25	19.11
Brass-85/5/5/5 (#115)—ingot	8.75	72.50	22.91
Steel-CR Alloy—strip	7.85	30.9-34.57	8.76-9.80
Steel—Hot Rolled Sheet	7.85	15.28	4.33
Steel-Stainless 304—bar	7.92	80.00	22.89
Iron-Pig, basic—pig	7.1	9.55	2.45

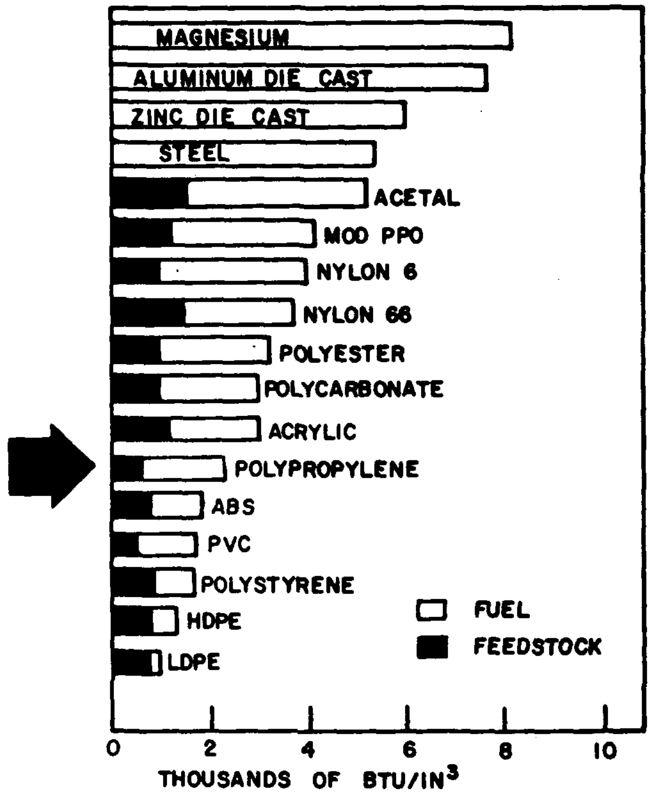


Figure 2.3 COMPARISON OF THE ENERGY REQUIREMENTS PER UNIT VOLUME BETWEEN METALS AND PLASTICS

limited to the following.

- o Injection Molding
- o Reaction Injection Molding
- o Rotational Molding
- o Blow Molding
- o Thermoforming
- o Compressive Molding

GARD's process investigation for the alternate material PVK indicated that of the above, injection molding and thermoforming are the two processes directly applicable to the fan blade parameters.

Injection molding, the most common process for shaping plastic, has the advantage of high hourly output for relatively thin section parts, such as the fan blade. Glass reinforced plastic is commonly molded using the injection molding process. Injection molding introduces the FRP compound into the mold cavity in an elevated temperature, fluid state. Hence, molding temperature for fabrication is a critical parameter. This is especially true since the key step in the injection molding process is the loading. The feed system must be properly designed and adjusted carefully during start up. If insufficient material is charged due to temperature, unfilled regions may develop in the mold cavity. This is specifically the problem encountered by industry in molding large diameter one-piece fans. Overfill can cause flashing and possible breakage during ejection.

Although the cost of injection mold tooling is initially high, the high part output rate in large production runs usually amortizes the investment in a reasonable time frame.

Thermoforming was considered a strong candidate for the fan blades. This is particularly true if the composite fan blade concept was utilized. The four blades can be easily fabricated using this process. Thermoforming involves flat plastic sheet stock cut to an approximate size, placed on a platen shaped to the product curvature. The plastic is then heated until the pliability state occurs. The material is formed against the platen by vacuum or a matching upper form. The material is then cooled until the section solidifies.

The process from an economic approach was considered more applicable to the performance of the subject program. The tooling is comparatively inexpensive. However, thermoforming does require some secondary trimming after the part is removed.

The preheated temperature for the fan material in the thermoforming process was anticipated to be 220°F (actual temperature proved to be 300°F). The predicted storage temperatures for the PVK fan are 140° maximum. This thermal environment will not effect the structural integrity of the fan blade or PVK during the fifteen year storage life.

2.2 Fan Blade Concept - Composite Construction

Since the one-piece molded 30 inch diameter fan was eliminated by the previous value analysis program, composite fan construction evolved as the primary method of approaching the fan blade design. Composite construction basically involves molding the four blades of FRP and mechanically fastening the blades to a spider hub of similar or dissimilar material.

The design of the fan blades, hub and assembly are discussed in the following subsections.

2.2.1 Fan Blade Design

The design approach to the individual fan blade configuration was basic. Since the steel production fan has proven effective in repeated air flow tests, it follows that duplication of the blade contour, shape and pitch in plastic would be appropriate as a baseline design. This approach is applicable if the rigidity of the plastic material is extremely high. The desired stiffness could be obtained if glass-reinforced plastics were utilized. Since the material search indicated that polypropylene (glass filled) was the leading candidate, a search for specific resins in that category were conducted. The material chosen as the best candidate was 30% glass filled polypropylene, chemically coupled. The specific material number is J-60/30/E, manufactured by the Fiberfil Division of Dart Industries located in Evansville, Indiana.

The physical properties of the material lend themselves well toward the known requirements. The material is extremely rigid, with tensile strengths of 12,000 psi or higher. It also has a low water absorption value (.05) which directly relates to long storage life. The glass fiber content of the material greatly reduces the creep or deformation of blade during storage conditions. The color of the plastic resin chosen is black, which will coordinate with the present alternate material PVK, and offers the best resistance to ultraviolet light (sunlight).

The cost of the resin material is approximately 70¢ per pound. It was estimated that the four (4) blades will weigh a total of 1.9 lbs which translates to $1.33 for raw material costs. Sufficient material was ordered from Fiberfill to construct two (2) fan blade assemblies for testing.

It was initially intended to build one fan blade assembly of .125 inch thick polypropylene and the second of .187 inch thick material. Preliminary deflection testing of the .125 thick material indicated that the thinner material had sufficient stiffness for the fan blade parameters. Therefore, in lieu of two different thicknesses, it was decided to construct both blade assemblies of the thinner material with two blade pitches. One assembly would incorporate a 20° blade pitch (identical to the present steel blade) and the second assembly would be formed to a 27° blade pitch.

The most economical method of generating the blade contours was elected. The steel blades of both a 20° and 27° pitch steel fans were removed from the hub for use as temporary tooling. Extruded sheets of .125 thick, 30% G. F. polypropylene were cut to the exact outside configuration of the steel blades. These patterns were inserted into an oven preheated to 300°F for a duration of 30 minutes. The patterns (now pliable) were removed and instantly placed and aligned on the top side of a steel blade. A second steel blade was placed on the upper side of the plastic pattern, sandwiching the plastic between the two steel blades. Clamps were applied and the blade was allowed to set up for a period of one hour. When the clamps were removed, the process resulted in a plastic blade which exactly represented the pitch and contour of the steel blade. Four blades of each pitch were generated by the above method for the prototypes.

2.2.2 Hub, Fan Blade

Various configurations of hub designs were investigated. The result of the hub design study indicated that the square configuration similar to the steel hub utilized on the present production fan offers the most advantages in fabrication and fan blade support. The drawing of this hub is shown in Figure 2.4.

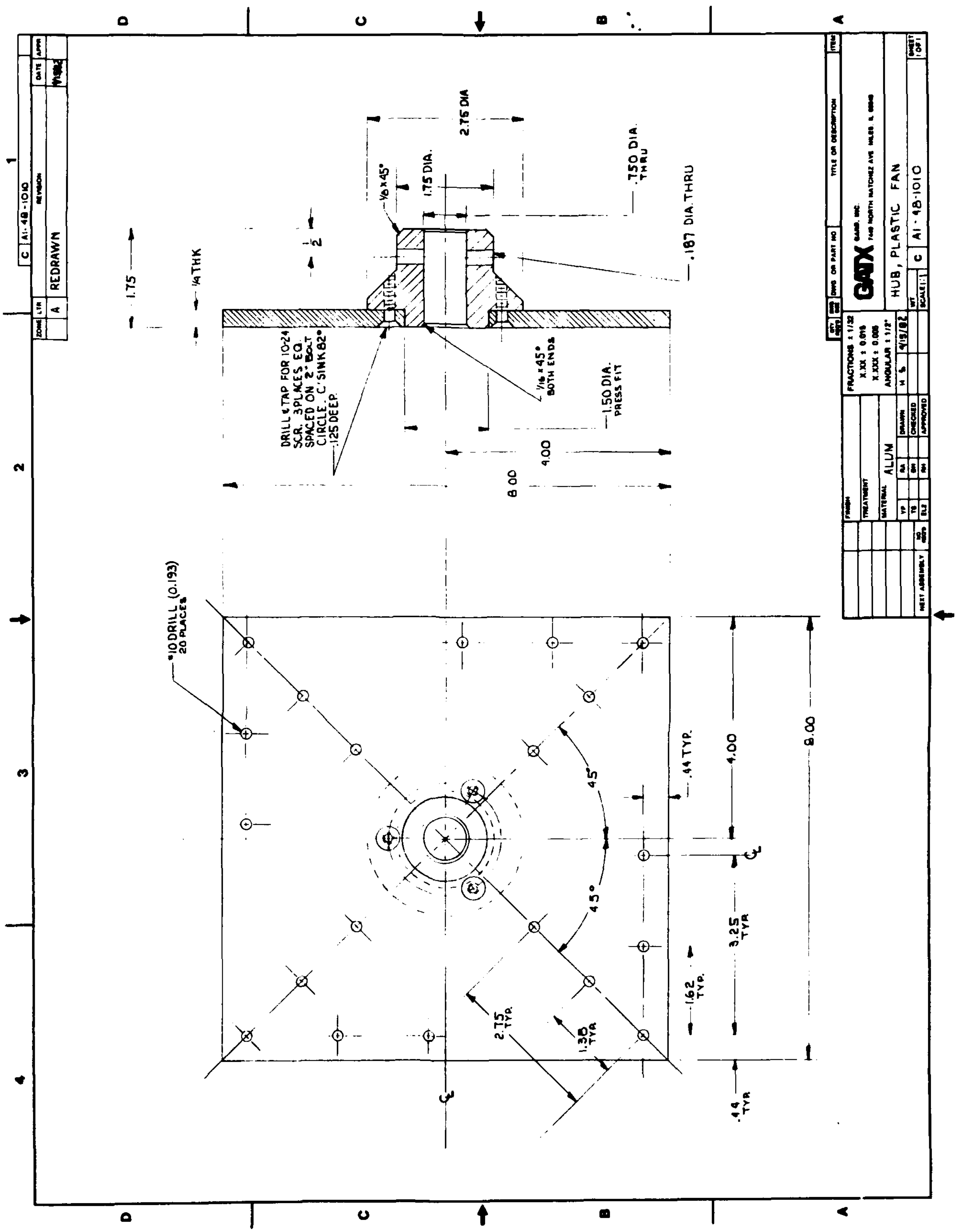


Figure 2.4 HUB, FAN

The extreme corners of the square support plate extend the fan blade support point to the maximum vertical depth possible. By providing the support as close to the fan tip as feasible, the rigidity of the fan blade is greatly enhanced. The mounting plate of the fan incorporates five (5) .187 diameter holes located in a geometric pattern for each fan blade attachment. The attachment of the hub to a PVK drive shaft is accomplished by means of a roll-pin. The rollpin connection is vibration proof and minimizes the removal of the fan for theft purposes.

Due to the cost of the tooling required for injection molding of the hub, the parts were fabricated from 5052 aluminum as shown in Figure 2.5. It is anticipated that the fan hub will be injection molded of 30% glass filled polypropylene, color black, on the production fan blade assembly. The cost estimates for the hub tooling and unit cost in plastic are included in this report.

2.2.3 Fan Blade Assembly

The fan blade assembly is shown in Figure 2.6. The plastic fan blades (4) are mechanically attached to the aluminum hubs using .187 diameter pull type rivets. The rivets, Number 1641-0621, are manufactured by the Avdel Corporation in Parsippany, New Jersey. They incorporate large diameter heads which increase the heading bearing surface, preventing pull through in the softer plastic blade material. The rivets can be installed by cartridge fed automatic installation tools at a rate of up to 2000 rivets per hour. The installed rivet is virtually vibration proof and provides two side clamp-up forces.

Figure 2.5 FABRICATED ALUMINUM HUB

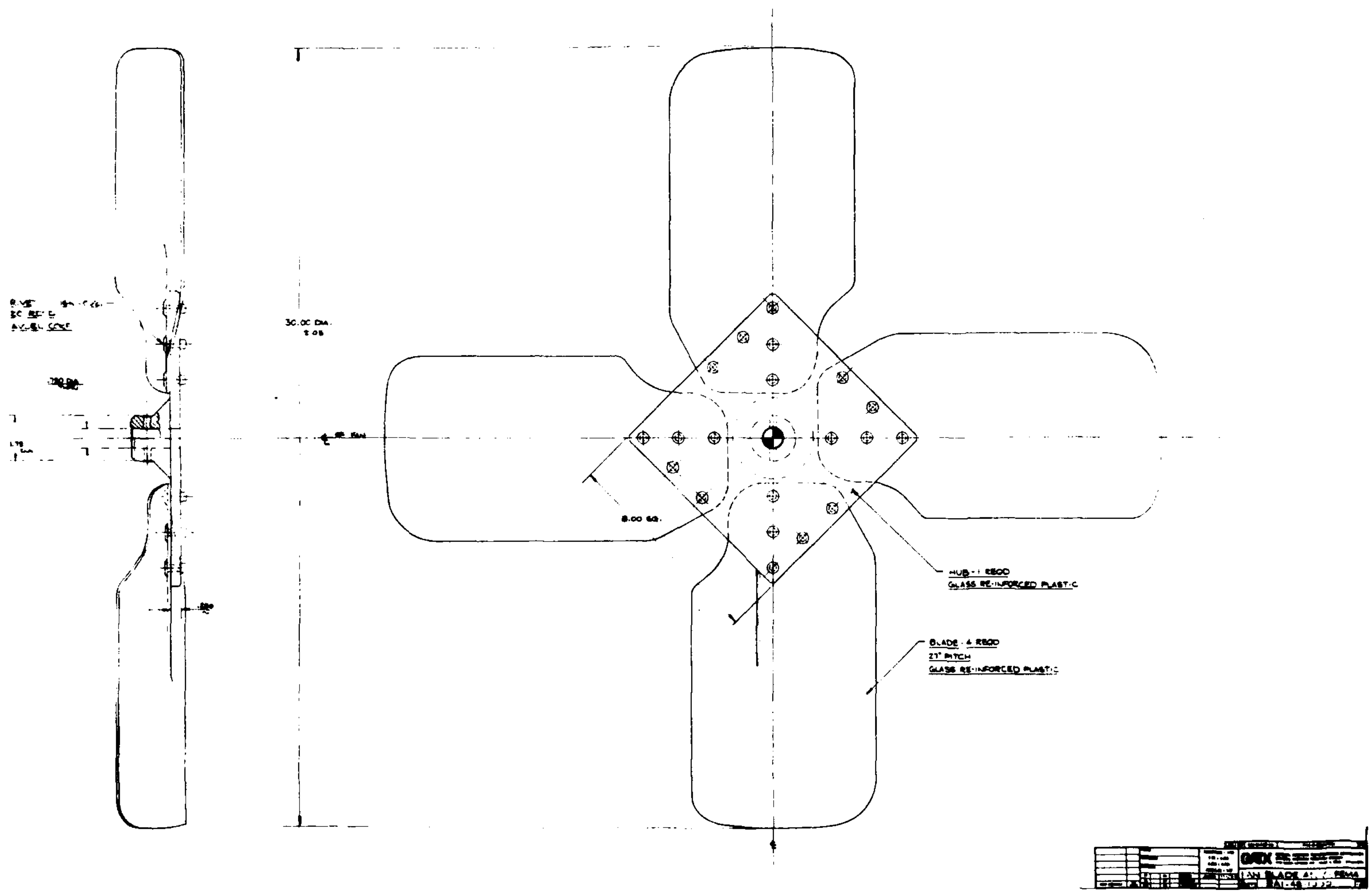


Figure 2.6 FAN BLADE ASSEMBLY

2.2.4 Fan Blade Prototype Construction

The first fan blade prototype fabricated was the 20° blade pitch model. The prototype is shown in Figure 2.7, along with the present production steel fan for comparison purposes.

Preliminary inspection of the fan indicated excellent rigidity of the assembly and exact contour of the plastic blades to those of the steel blades.

The fan assembly, with the aluminum hub, weighs 3.87 pounds. The aluminum hub alones weighs 1.90 pounds. When this part is molded of plastic it would weigh approximately .70 pounds resulting in a production fan weight of 2.67 pounds. This represents a savings in weight over the production steel fan (9.9 lbs) of 7.23 pounds, or approximately 73%.

Figure 2.8 shows the fully assembled plastic fan next to the existing steel fan on a pedal ventilator kit.

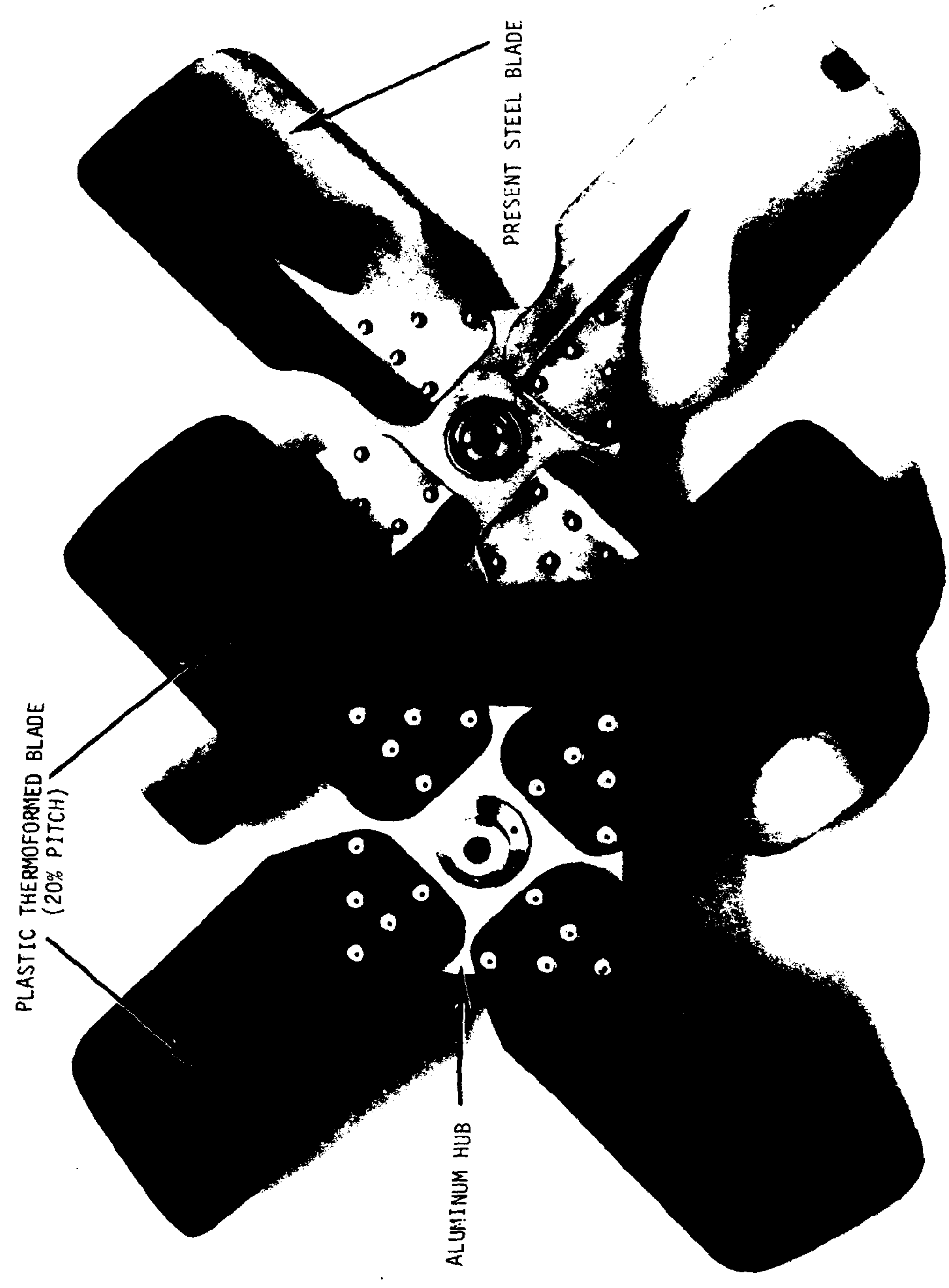


Figure 2.7 PLASTIC AND STEEL FAN COMPARISON

Figure 2.8 PLASTIC FAN AND PVK

Section 3

FAN VALIDATION TESTS

To determine the air flow performance and structural inegrity of the two prototype fans, GARD subjected the fans to a series of validation tests. The tests included blade deflection studies, air flow, endurance and environmental resistance. The procedures and results of the fan validation tests are described in this section.

3.1 Fan Blade Deflection Tests

Two different test procedures were utilized on both the 20° and 27° pitch plastic fans to determine the blade deflection at the tip and at the contour under load (at 480 RPM). Since the present production fan is constructed of 0.050 thick steel blades, there is virtually zero deflection at the specified speed. It was known, before construction of the prototype fans, that some deflection of the blades was likely under load. GARD used both high speed photography and electronic strobe lights to determine the blade deflection. These tests are described in the following subsections.

3.1.1 Blade Tip Deflection

The test setup for the blade tip deflection test is shown in Figure 3.1. The plastic fan is mounted in a commercial type exhaust fan housing with an integral shroud. The fan is driven at 485 RPM with a 1/3 horsepower electric motor and belt drive. The fan blades are marked with yellow adhesive tape to identify the blade number during high speed photography. The camera located to the right is a 16-mm Teledyne, Model No. DMB-55. A clearance gauge indicator is attached to the fan shroud for measuring deflection.

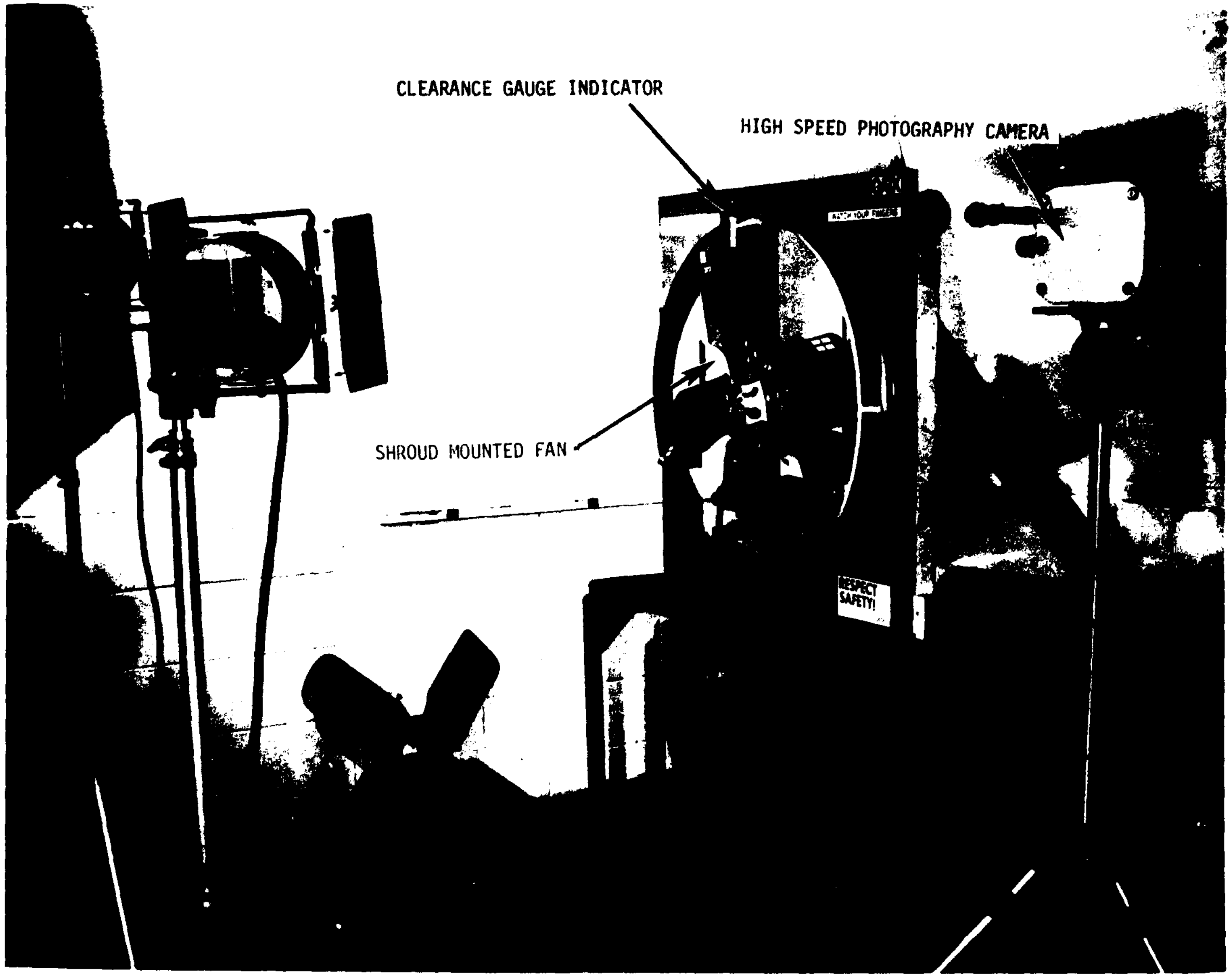


Figure 3.1 BLADE TIP DEFLECTION TEST SETUP

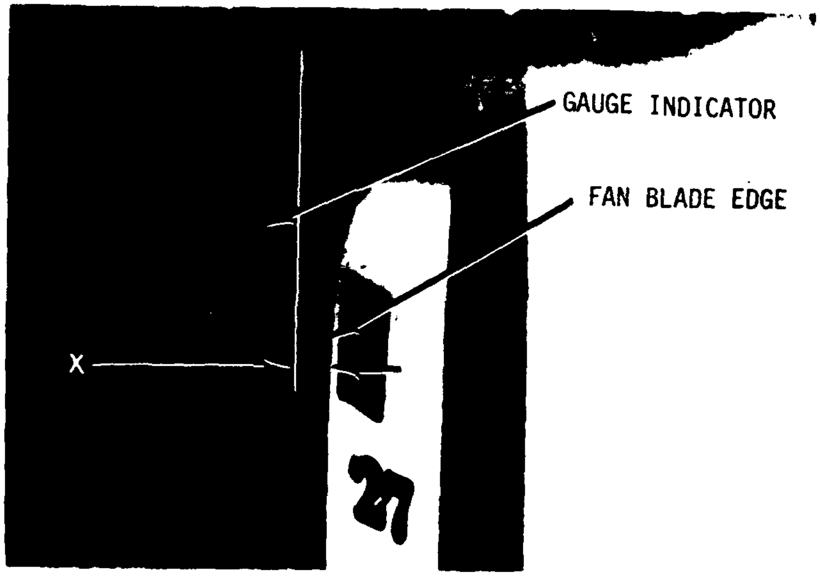
The test procedure involved positioning each blade at the 12 o'clock position, adjacent to the fixed gauge indicator. With the blade in the static position (not rotating), the high speed camera was energized at a speed of 200 feet per second. After two seconds, the fan was powered, and the camera recorded five seconds of the blade under load at 485 RPM. Figure 3.2 graphically shows the static and dynamic segments taken from the footage. The films were projected on a screen and actual linear measurements were taken for each blade at the static and full load positions.

The blade deflections were considered minimal (for both plastic fans). The maximum deflection recorded at the blade tip for all 8 blades was 0.160 inches. It was GARD's conclusion that this would not significantly effect the air delivery of the fans.

3.1.2 Contour Deflection Test

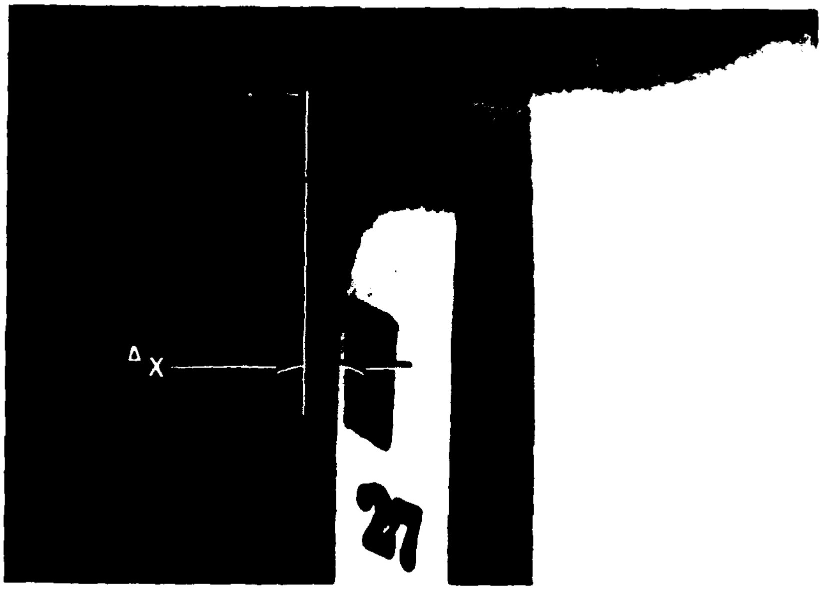
The configuration for the blade contour deflection test is shown in Figure 3.3. The plastic fans were again mounted and driven by the commercial fan support housing. Focused on the center of the fan hub is a General Radio No. 1540-54, "Strobolume" electronic strobe light. Each individual blade was synchronized with the strobe light to obtain a "frozen" image at a given point. Upon detailed visual inspection of each blade no contour deflection or flutter was observed. This was anticipated since the extruded plastic sheet from which the blades were thermoformed was stronger in cross-section than length. This is due primarily to the glass orientation during that particular material extrusion run.

In summary, the plastic blades for both the 20° and 27° pitch exhibited excellent cross-sectional rigidity (contour) under operational load.



(A)

DIMENSION TAKEN OF DISTANCE (X) BETWEEN FAN BLADE LEADING EDGE AND GAUGE INDICATOR WHILE BLADE IS IN STATIC MODE.



(B)

DIMENSION TAKEN AT SAME POINT AFTER FAN BLADE OBTAINS FULL LOAD RPM OF 480.

Figure 3.2 BLADE TIP DEFLECTION TEST

GARD, INC


SHROUD MOUNTED FAN
ELECTRONIC STROBE LIGHT

3.1.3 Air Flow Tests

Three fans were tested for air flow performance comparison. The present production PVK steel fan was tested first to determine the data baseline. Following this test, the two plastic fans, 20° and 27° pitch blades, were tested under identical test conditions. The tests conformed to the parameters of AMCA-210-74, ASHRAE Standard 51-75, titled "Laboratory Methods of Testing Fans for Rating". All three fans were tested with the PVK shroud intact.

The Air Moving and Conditioning Association (AMCA), located in Arlington Heights, Illinois, was given the subcontract for performance of the above air flow testing. The test configuration schematic is shown in Figure 3.4. The fans for the test were mounted as shown in Figures 3.5 and 3.6. The test fan volume handled is varied by regulating the variable supply system. The tests cover the entire range of performance from free delivery (air volume at zero static pressure) to 300 CFM (high static pressure). At each of the eight points of operation the pressure differential across the nozzle is measured and the total pressure (suction) at the fan inlet is measured. These measurements are translated mathematically to air volume and air pressure.

The three test fans were driven at 480 RPM by a dynamometer which provided values of torque at each of the operating points while readings of fan speed (RPM) were taken at the same time. This allowed for calculations of the horsepower input for each of the settings. Simultaneously, readings were taken of the wet and dry bulb temperature and barometric pressure so that the actual air density could be calculated. The measured and calculated values can then be plotted to develop the fan performance curves. In this case the performance curves were calculated and plotted automatically through a Hewlett Packard computer. The complete testing data package by AMCA is included in Appendix B of this report.

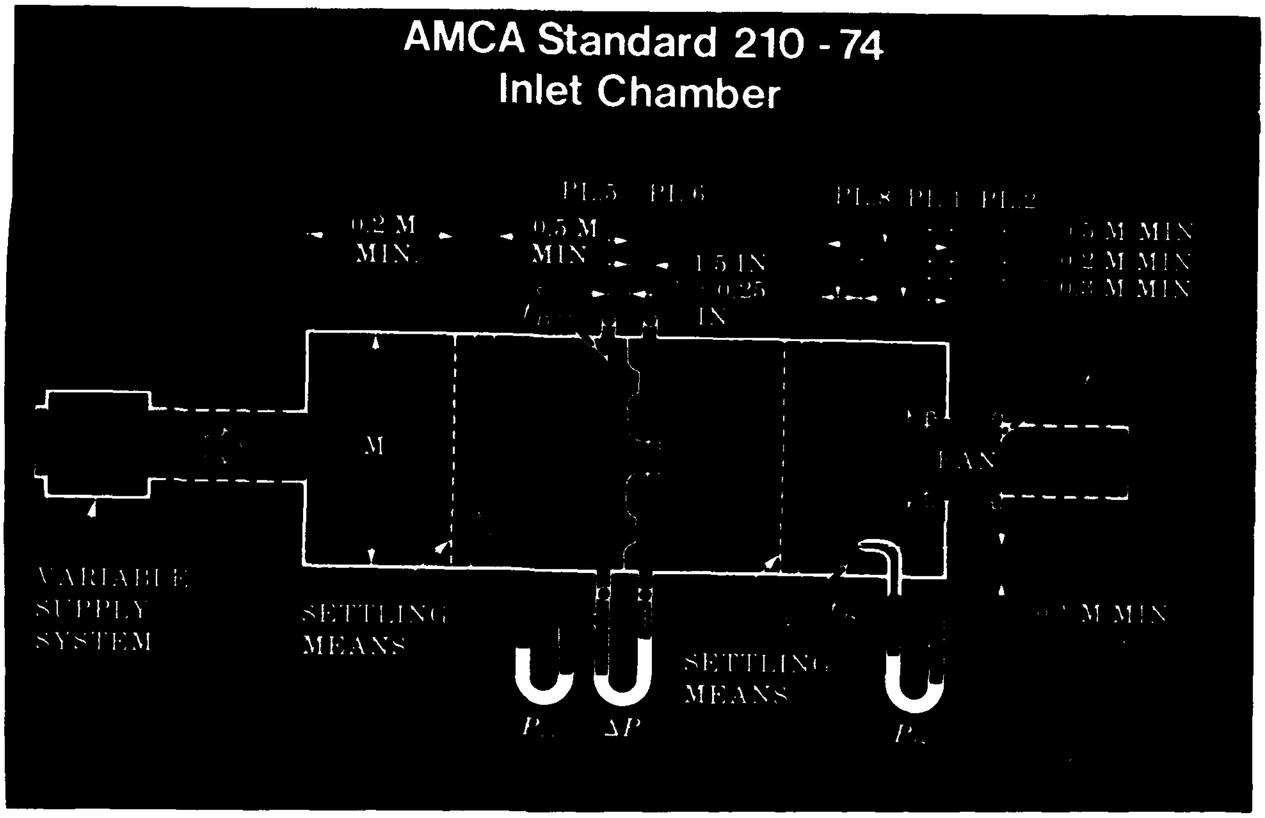


Figure 3.4 TEST CONFIGURATION SCHEMATIC

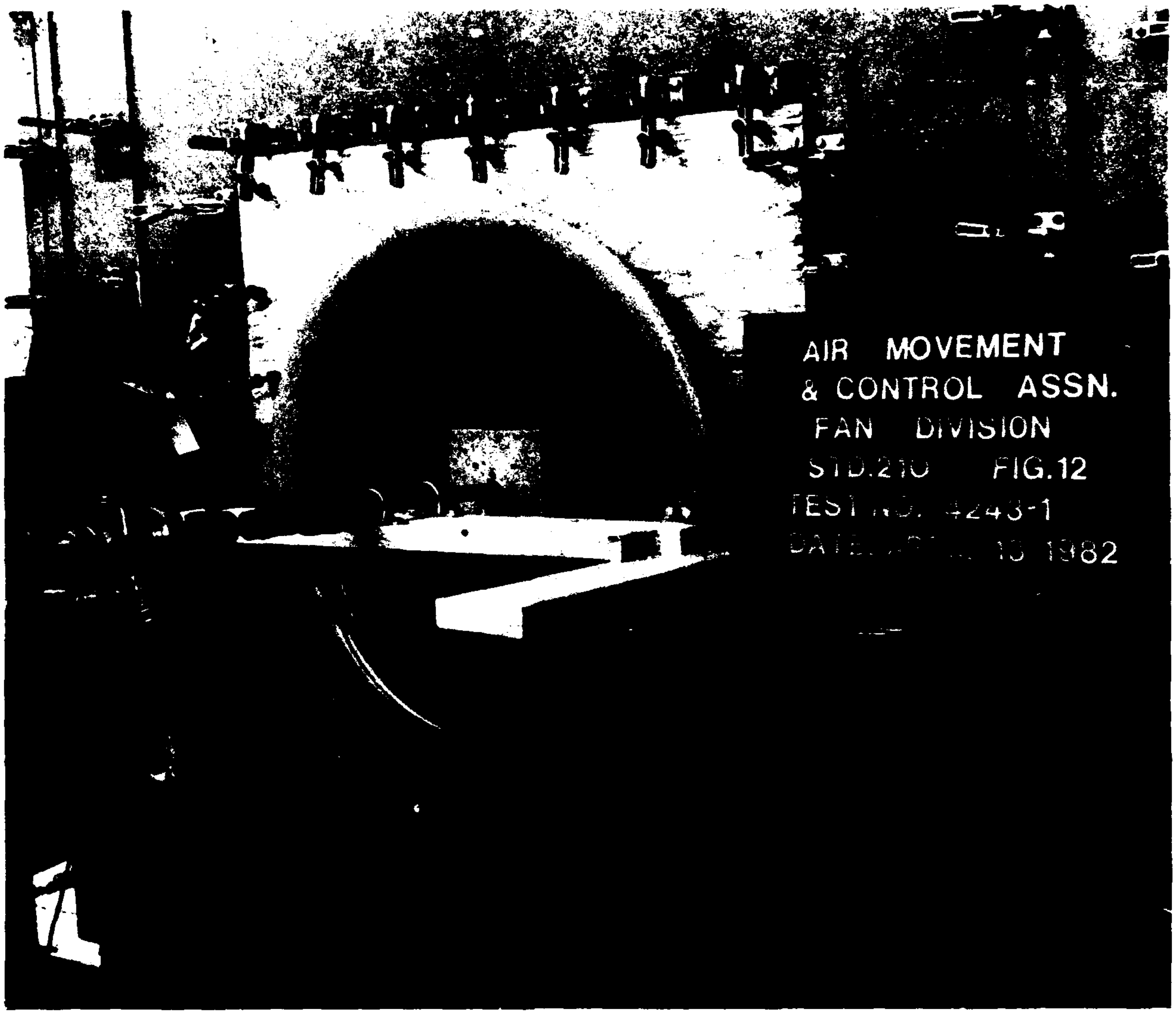


Figure 3.5 FAN SETUP - 27° PITCH PLASTIC FAN

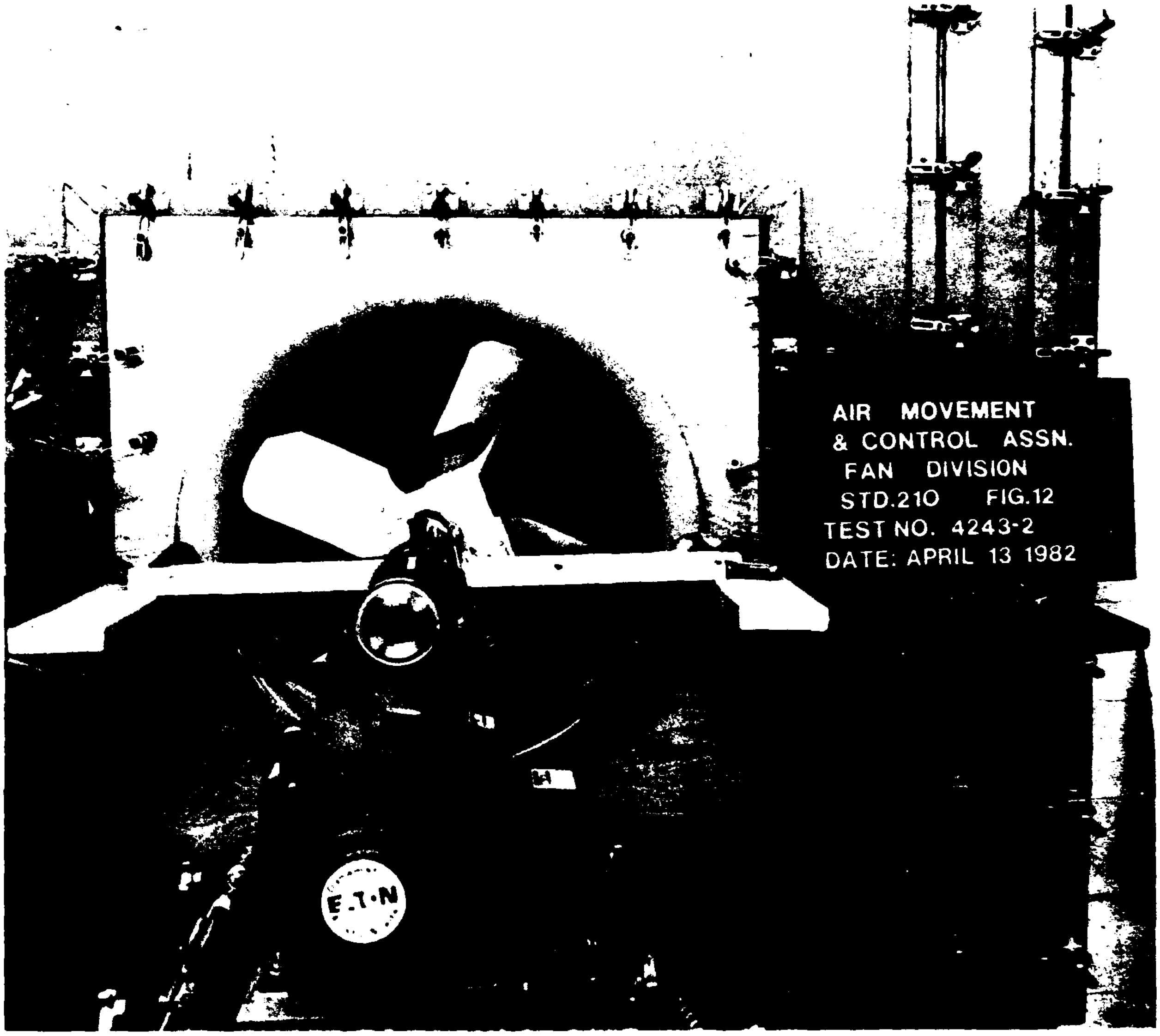


Figure 3.6 FAN SETUP - 20° PITCH STEEL BLADE

GARD, INC.

The performance curves for all three fans are superimposed in Figure 3.7 for comparison purposes. It is noted the 27° pitch plastic fan (4750 CFM) exceeds the steel fan (4500 CFM) by 250 CFM at free air flow, zero static pressure. The 20° pitch plastic fan free flow rate at 4000 CFM is 11% below the steel fan. The pressure losses in a 50 foot long - 30 inch diameter duct (straight - no elbows) would present a static pressure of approximately .10 IN. WG. Therefore, it can be extrapolated that the typical approximate air flow for the three fans under operational conditions would be, respectively; 27° plastic - 3600 CFM, 20° steel - 3400 CFM, and 20° plastic - 3000 CFM.

The related horsepower inputs for all three fans are relatively close. The 20° plastic fan is the lowest horsepower at .09, and the steel and 27° plastic fan are essentially the same at .104 HP.

The projected horsepower inputs at the PVK operational configuration are, respectively; 20° plastic - .11 HP, 20° steel - .126 HP, and the 27° plastic - .13 HP.

It can be concluded from the fan performance graphs that both the 20° or 27° plastic fans offer a viable alternate to the present steel production fan. However the 27° plastic fan represents the most cost-effective unit based on performance. Its free air flow is 6% higher than the steel fan, and 16% greater than the 20° plastic fan. The horsepower input is virtually identical to the steel fan and 15% higher than the 20° plastic fan at operational conditions. The manufacturing costs for both plastic fans are the same.

3.1.4 Endurance Test -Plastic Fans

A mechanical endurance test of both plastic fans was performed to determine the integrity of the fan assemblies during the anticipated shelter operation of two weeks (336 continuous hours). The blades were mounted in the

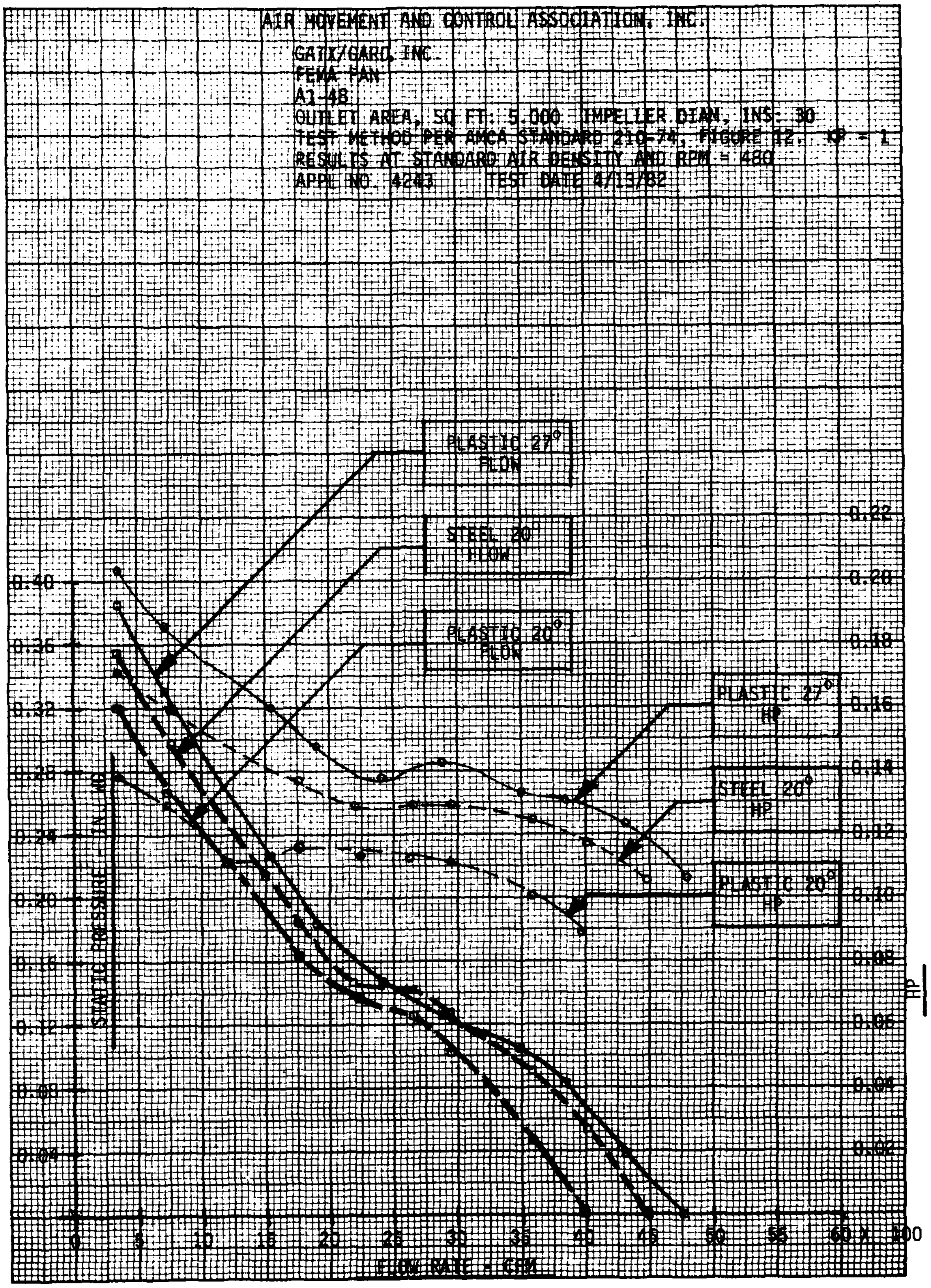


Figure 3.7 FAN COMPARISON CURVES

commercial housing previously discussed, and motor driven at 485 RPM. At the start of each work day the test fan was shut-down for a brief period to check the following components.

- o Each plastic blade for splits or cracks
- o Integrity of rivets
- o Hub slippage on shaft
- o Looseness of blade to hub
- o Contour of blade

The actual test run duration for each blade was 355 hours for the 20° pitch blades and 345 hours for the 27° pitch blades. No visual degradation of any blade or other component of the fan assemblies was observed during the endurance tests. It can be safely projected that the operational life of both fans could be in excess of 12 months as opposed to weeks.

3.1.5 Environmental Testing - Plastic Fans

Environmental tests were performed at Gaynes Testing Laboratories in Chicago, Illinois and supervised by GARD technical representatives. Only the plastic 27° fan was subjected to the tests since it represented the optimum air flow performance, and was considered the most susceptible to blade deformation due to the increased rake (pitch) of the formed blade. The primary purpose of the environmental tests was to determine the fan assembly's resistance to varying ambient temperatures that may be encountered in shelter storage conditions.

GARD utilized the identical test procedures prescribed for the Alternate Material PVK frame. The test procedures, high temperature and low temperature, are extracted from the specifications listed in MIL-STD-810C, titled "Environmental Test Methods". This standard establishes uniform test methods for

determining the resistance of military equipment to the effects of natural and induced environments peculiar to military operations. The specifics of the high and low temperature tests is to determine the effects of temperature extremes on the PVK frame without protective packaging.

The fan blades were tested in a Murphy and Miller sealed temperature chamber. The cycling of the chamber is controlled automatically by a timed cam-operated thermostat. The specific test procedures were conducted as follows:

Prior to placement inside the test chamber, each of the four plastic blades will be checked for blade curvature and straightness using a steel blade supplied by GARD as an inspection gage tool.

At the end of each test sequence the blades will be rechecked with the gage tool to assure no warpage has occurred. In addition, a visual inspection of each blade will be performed to detect possible fractures or structural degradation.

Procedure No. 1 - High Temperature

A. Temperature maintained at 60°C (140°F) - 48 hrs. - Low Relative Humidity.

B. Temperature reduced to 110°F to stabilization of frames.

C. Inspection.

D. Temperature reduced to room ambient.

E. Inspection & Measurement (using steel blade).

Procedure No. 2 - High Temperature Cycling

A. Temperature raised to 49°C (120°F) and held for 6 hours.

B. Temperature raised within 1 hour to 60°C (140°F) and held for 4 hours.

C. Temperature lowered with 1 hour to 49°C (120°F).

D. Repeat steps A, B & C for a total of 3 complete cycles.

E. Temperature reduced to 110°F to stabilization of frames.

F. Inspection.

G. Temperature reduced to room ambient.

H. Inspection & Measurement (using steel blade).

Procedure No. 3 - Low Temperature

A. Temperature reduced to -34°C (-30°F) and held for 24 hours.

B. Temperature raised to room ambient.

C. Inspection & Measurement (using steel blade).

D. Repeat steps A, B & C.

At the conclusion of each phase of above testing, the plastic fan was visually inspected and checked with the steel gage. The fan assembly remained in the same relative condition at the end of each test procedure sequence and at the conclusion of the test. There was no apparent distortion, warpage or change in the components from a material standpoint or in relation to the overall assembly position when compared to the provided contour gage.

The test report submitted by Gaynes Testing Laboratories is included in Appendix C of this report.

3.1.6 Construction of Prototype Fans

Since the 27° pitch plastic fan was chosen as the most cost-effective of both plastic fans, fifteen (15) prototype models of this fan were fabricated and assembled. Of these, it is anticipated that 10 fans would be delivered to the Defense Logistics Agency, 1 to FEMA (Civil Defense) and 4 retained at GARD for incorporation on GFE PVKs.

Section 4

PRODUCTION COST ESTIMATES

PLASTIC FAN - 27° BLADE PITCH

Estimates of production costs for the plastic fan were based on a target procurement quantity of 100,000 units each. The tooling required and amortization for same are included in the estimates. The costs shown are derived from discussions with vendors and suppliers based on the above stated quantities.

The cost summary for the plastic fan shown in Figure 4.1 includes materials, labor, burdens, profit and represents the total estimated procurement cost for the newly developed fan.

Without applying escalation factors to the steel fan, 1980 unit cost of $15.54, the estimated final price of the plastic fan at $9.41 each represents a savings of $6.13 each.

In addition to the reduction of the fan manufacturing costs, significant savings can be realized in the shipment/transportation of the unit. The plastic fan, with injection molded hub, will weigh approximately 2.67 pounds. This represents a weight reduction of some 7.2 pounds over the steel fan assembly (9.9 lbs).

Based on an overland shipment (truck) charge of 22¢ per pound for a typical 800 mile destination radius, the savings per fan would be $1.58. This translates to an approximate savings of $150,000 in shipment charges for the projected 100,000 PVK procurement quantities.

1982 PRODUCTION COST ESTIMATES

(100,000 UNIT PROCUREMENT)

PLASTIC FAN - 27° PITCH

FAN BLADE

QTY REQD	DESCRIPTION	COST EACH	COST/ASSY
4	* Formed Polypropylene Blades	$ .65	$ 2.60
1	** Injection Molded Hub	2.10	2.10
20	Rivert, Blind	.03	.60
	SUBTOTAL - MATERIALS		$ 5.30
	LABOR - 2 Min Drilling Holes		$ .92
	3 Min Assembly		1.38
	SUBTOTAL - LABOR		$ 2.30

* Includes amortization of vacuum form tooling .05 cents per unit or $5,000.

** Includes amortization of injection mold tooling at .18 cents per unit or $18,000 (4 cavity mold)

GARD, INC.

PLASTIC FAN TOTALS

LABOR - 5 Min @ $27.50 Hr.	=	$ 2.30
MATERIALS		5.30
MATERIAL BURDEN (10.5%)		.56
G&A (.70% of Burden)		.39
		$ 6.25

TOTAL COST	$ 8.55
PROFIT	.86
TOTAL PRICE - PLASTIC FAN	$ 9.41

Section 5

RECOMMENDATIONS

The following recommendations are made as a result of the work completed under this contract.

PRESSURE DUE TO SURFACE WINDS

GARD is currently conducting wind tunnel testing of scaled model shelter configurations to determine ventilation characteristics. This testing has indicated that a surface wind of 15 MPH or greater whose direction is against the PVK ducting outlet opening may cause a backpressure sufficient to reduce the fan CFM output 50% or more. Preliminary data warrants further investigation devoted to ambient wind effects on the PVK. In addition, outlet opening wind deflectors, revised operational instructions, and alternate aperture selection schemes would be studied as candidates for negating wind effects.

FAN HUB INNOVATIONS

Since the fan hub is now an injection molded plastic part, certain innovations to the hub can be incorporated at no cost per piece part. For instance, a drive pulley can be molded into the hub. This pulley could provide the power take-off for driving a generator, additional ventilating devices, such as the KPK, and other auxiliary equipment.

PRODUCTION DATA PACKAGE - FAN

Additional work is necessary to bring the present PVK fan prototype to a state of procurement readiness. Specifically, a production drawing package, quality assurance and documentation control plans are required. These tasks

could be incorporated as a add-on to the pedal ventilator production data package.

BLAST WAVE EFFECTS TESTING

The plastic fan developed under this program remains to be tested for blast wave effects. It is recommended that next series of blast upgrading testing, such as "MILL RACE", include alternate material PVKs that have both steel and plastic fans. This would provide realistic comparative data for both fans.

Section 6

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1. A. L. Kapil, H. M. Sitko and J. M. Buday, "Ventilation Kits", OCD Work Unit 1423D, GARD Report 1477, General American Research Division, Niles, Illinois, November 1969.

2. J. M. Buday and R. J. Klima, "Development of Two Types of Ventilators", DCPA Work Unit 1423E, GARD Final Report 1703, GARD, INC., Niles, Illinois, April 1979.

3. J. M. Buday, et al, "Study of Alternate Material for Pedal Ventilator Kits", GARD Final Report A1-16, (1724), GARD, INC., Niles, Illinois, June 1980.

4. Nicholas P. Cheremisinoff and P. N. Cheremisinoff, Fiberglass Reinforced Plastics Deskbook, 1978, Ann Arbor Science Publishers, Inc.

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APPENDIX A

FAN BLADE PRELIMINARY SPECIFICATION

(To be incorporated in the Pedal Ventilator Kit Specifications as a Revision of Section 3.2 of that Specification.)

3.2 Fan

The fan configuration shall conform to the configuration depicted on the preliminary drawing, Number EA1-48-1000. The fan diameter shall be 30.00 ± .05 inches (tip diameter), and the trailing edges of all four (4) blades shall be in line within .10 inches. The fan bore shall be .750 $^{+.002}_{-.000}$ inch diameter. The fan rotation shall be clockwise (facing air discharge), and the leading edge shall be from 1/8 to 1/4 inch from the air discharge side of the shroud such that the fan does not project beyond the shroud. The fan shall be equal to and interchangeable with the fan depicted in EA1-48-1000 and shall meet or exceed performance requirements stated in Figure 2. The fan as defined in the drawing shall be fabricated to the specifications below.

3.2.1 Fan Blade - Four (4) Required

3.2.1.1 Base Material - Polypropylene premixed resin, fiberfill No. J-60-30-E (BK233) or equivalent.

3.2.1.2 Glass Re-inforcement Material - 1/4 inch long chopped glass strand glass fiber, Owens Corning No. K885 or equivalent.

3.2.1.3 Pigment - The pigment shall be pelletized or powdered concentrate No. BK233 (Fiberfill) flat black or equivalent.

3.2.1.4 The Mix Ratio shall be approximately 68% baseresin, 30% chopped glass fiber, and 2% pigment.

3.2.1.5 Process - The process shall be injection molded or thermoforming (vacuum or matched mold).

3.2.1.6 Blade Configuration - The fabricated blade shall conform in outline, contour and pitch (27°) of a Torin steel blade, Number R-3027-4, or equivalent.

The plastic blade thickness shall be .120 ±.005. The five mounting holes per blade shall be produced by coreing the injection mold tooling or by multiple punches if blade is thermoformed.

3.2.2 Hub, Fan - One (1) Required

3.2.2.1 Base Material - Polypropylene premixed resin, fiberfill No. J-60-30-E (BK23) or equivalent.

3.2.2.2 Glass Re-inforcement Material - 1/4 inch long chopped glass strand glass fiber, Owens Corning No. K885 or equivalent.

3.2.2.3 Pigment - The pigment shall be pelletized or powdered concentrate No. BK233 (Fiberfill) flat black or equivalent.

3.2.2.4 The mix ratio shall be approximately 68% baseresin, 30% chopped glass fiber, and 2% pigment.

3.2.2.5 Process - The process shall be injection molded.

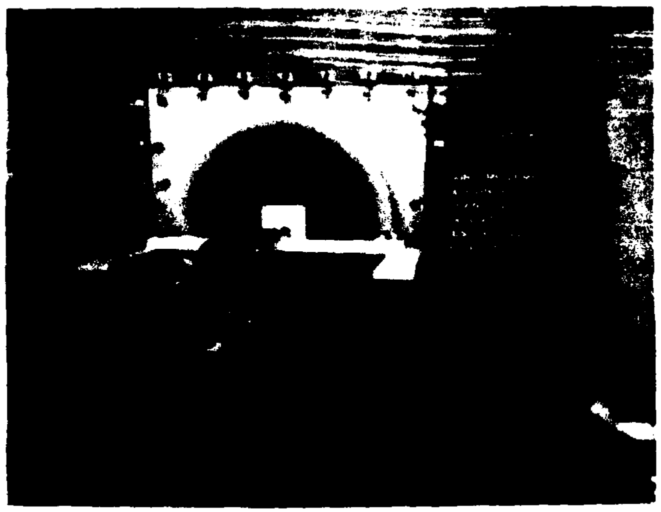
3.2.2.6 Hub Configuration - The fabricated hub shall conform to drawing Number CA1-48-1010. The mounting holes (20) shall be produced by cores in the injection mold tooling. The .187 diameter hole for the roll pin shall be drilled after the molding process.

3.2.3 Fan Assembly

The blades (4) shall be mechanically fastened to the hub using Avdel Blind Rivet No. 1641-0621 or equivalent. For pneumatic tool installation, the tool input is to be 35 psi minimum.

APPENDIX B

TEST RESULT DATA BY AIR MOVEMENT AND CONTROL ASSOCIATION - FAN TESTING PER AMCA STANDARD 210-74



AIR MOVEMENT & CONTROL ASSOCIATION, INC. - TEST LABORATORY

```
200 DATA 0,0,1,0,480
201 DATA 1,0.83317,0.83317,0,4.665,475,73.1,73.2,71.9,59.6,29.22,73.9,205
202 DATA 2,0.035,3.77,475,73.1,73.2,71.9,59.6,29.22,73.9,240
203 DATA 3,0.075,2.985,475,73.1,73.1,71.8,59.6,29.22,74,255
204 DATA 4,0.095,2.48,475,73.1,73.1,71.8,59.6,29.22,74,260
205 DATA 5,0.115,1.69,476,73.2,73.2,72.8,60.2,29.22,74.1,280
206 DATA 6,0.135,1.185,476,73.2,73.2,72.8,60.2,29.22,74.1,270
207 DATA 7,0.17,0.735,476,73.8,73.8,73,60.3,29.22,74.3,290
208 DATA 8,0.21,0.485,476,73.8,73.8,73,60.3,29.22,74.3,315
209 DATA 9,0.31,0.105,476,74.4,74.4,74.1,60.9,29.22,73.9,365
210 DATA 10,0.36,0.025,476,74.4,74.4,74.1,60.9,29.22,73.9,400
```

AIR MOVEMENT & CONTROL ASSOCIATION, INC.

APPLICATION NO. 4243
TEST NO. 4243-1
DATE OF TEST 4/13/82

TEST UNIT:
MANUFACTURER: GATS GARD INC.
TRADE NAME: FEMA FAN
MODEL NO: A148
IMPELLER DIAM, INS: 30
OUTLET AREA, SQ FT: 5.0900

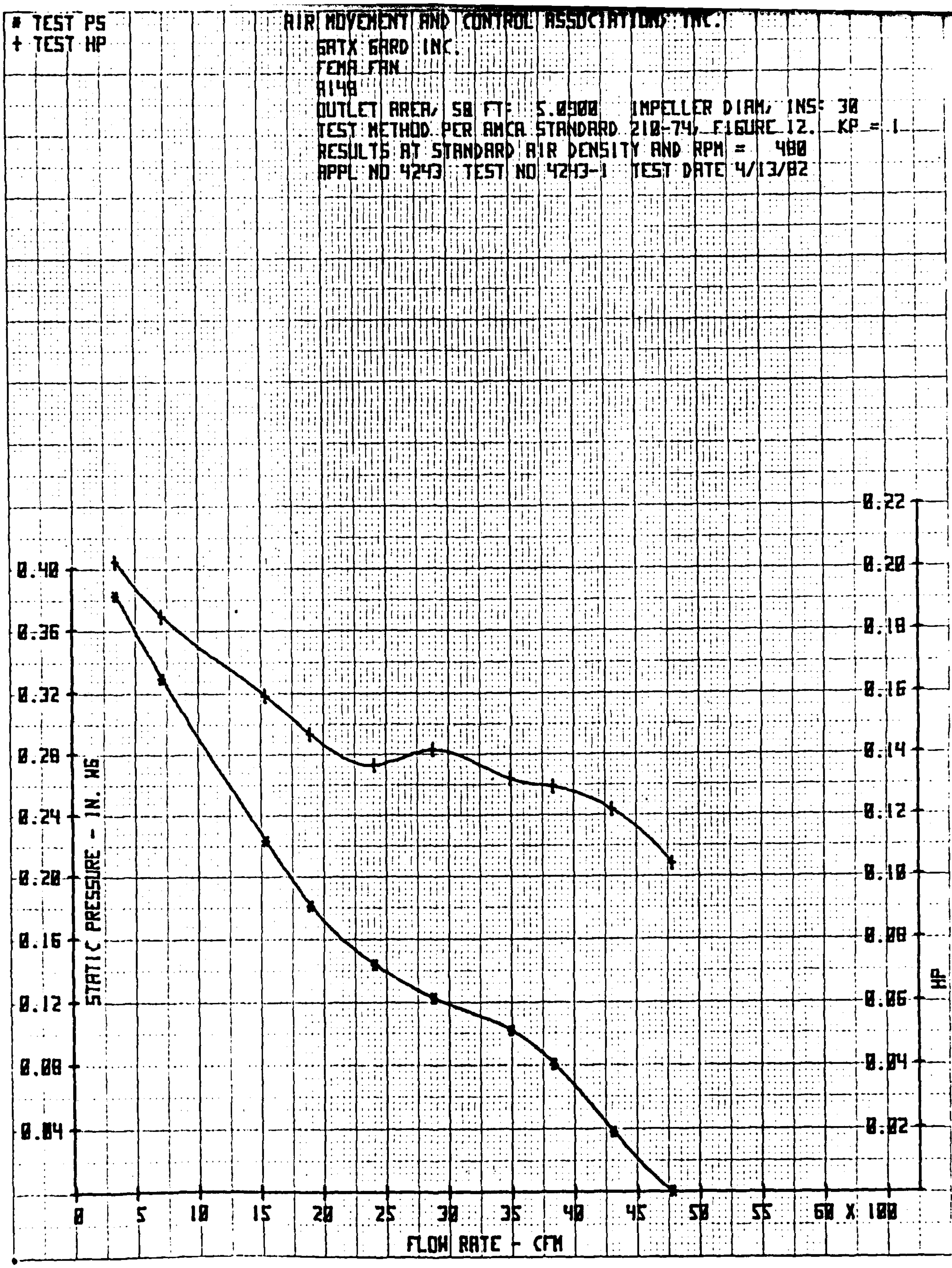
TEST METHOD PER AMCA STANDARD 210-74, FIGURE 12. CALCULATIONS BASED ON INCOMPRESSIBLE FLOW CONDITIONS (KP>0.99). KP = 1 USED THROUGHOUT.
REMARKS: CONTRACT TEST(PLASTIC WHEEL,27 DEG. BLADE)

RESULTS AT TEST CONDITIONS:

DET	PB	DENSITY	RPM	PT	PV	PS	CFM	HP	%NT	%NS
1	29.090	0.07203	475	0.052	0.052	0.000	4732.4	0.097	39.94	0.00
2	29.090	0.07203	475	0.077	0.042	0.035	4257.6	0.113	45.56	20.72
3	29.090	0.07203	475	0.108	0.033	0.075	3791.1	0.120	53.71	37.2[illegible]
4	29.090	0.07203	475	0.123	0.028	0.095	3456.4	0.122	54.41	42.14
5	29.090	0.07200	476	0.134	0.019	0.115	2853.9	0.132	45.43	39.0[illegible]
6	29.090	0.07200	476	0.148	0.013	0.135	2389.1	0.127	43.67	39.7[illegible]
7	29.089	0.07192	476	0.178	0.008	0.170	1881.1	0.137	38.48	36.[illegible]
8	29.089	0.07192	476	0.215	0.005	0.210	1526.5	0.149	34.76	33.[illegible]
9	29.090	0.07184	476	0.311	0.001	0.310	706.6	0.172	20.0[illegible]	19.[illegible]
10	29.090	0.07184	476	0.360	0.000	0.360	342.1	0.189	10.26	10.[illegible]

RESULTS AT STANDARD FAN AIR DENSITY AND RPM = 480

DET	PT	PV	PS	CFM	HP	%NT	%NS
1	0.055	0.055	0.000	4782.2	0.104	39.94	0.00
2	0.082	0.045	0.037	4302.4	0.121	45.56	20.72
3	0.115	0.035	0.080	3831.0	0.129	53.71	37.21
4	0.130	0.029	0.101	3492.8	0.132	54.41	42.14
5	0.142	0.020	0.122	2877.9	0.141	45.43	39.03
6	0.157	0.014	0.143	2409.2	0.136	43.67	39.78
7	0.189	0.009	0.180	1896.9	0.146	38.48	36.72
8	0.228	0.006	0.223	1539.3	0.159	34.76	33.89
9	0.330	0.001	0.329	712.6	0.184	20.06	19.98
10	0.382	0.000	0.382	345.0	0.202	10.26	10.25



TEST NO. 4243-1, PLASTIC FAN - 27° BLADE PITCH

AIR MOVEMENT & CONTROL ASSOCIATION, INC. - TEST LABORATORY

```
200 DATA 0,0,1,0,480
201 DATA 1,0.83317,0.83317,0,4.225,482,71.6,74.6,71.9,59.8,29.28,74.7,210
202 DATA 2,0.05,3.38,482,74.6,74.6,71.9,59.8,29.28,74.7,235
203 DATA 3,0.085,2.7,482,74.5,74.5,73.2,60.3,29.28,74.7,250
204 DATA 4,0.12,1.83,482,74.5,74.5,73.2,60.3,29.28,74.7,260
205 DATA 5,0.135,1.40,482,73.2,73.2,73.6,60.5,29.28,74.7,260
206 DATA 6,0.14,1.01,482,73.2,73.2,73.6,60.5,29.28,74.7,260
207 DATA 7,0.175,0.655,482,74.2,74.2,74.2,60.8,29.28,74.8,275
208 DATA 8,0.205,0.475,482,74.2,74.2,74.2,60.8,29.28,74.8,285
209 DATA 9,0.285,0.125,482,74.9,74.9,74.9,61.1,29.28,74.9,320
210 DATA 10,0.34,0.025,482,74.9,74.9,74.9,61.1,29.28,74.9,345
```

AIR MOVEMENT & CONTROL ASSOCIATION, INC.

APPLICATION NO. 4243
TEST NO. 4243-2
DATE OF TEST 4/13/82

TEST UNIT:
MANUFACTURER: GATX GARD INC.
TRADE NAME: FEMA FAN
MODEL NO: A148
IMPELLER DIAM, INS: 30
OUTLET AREA, SQ FT: 5.0900

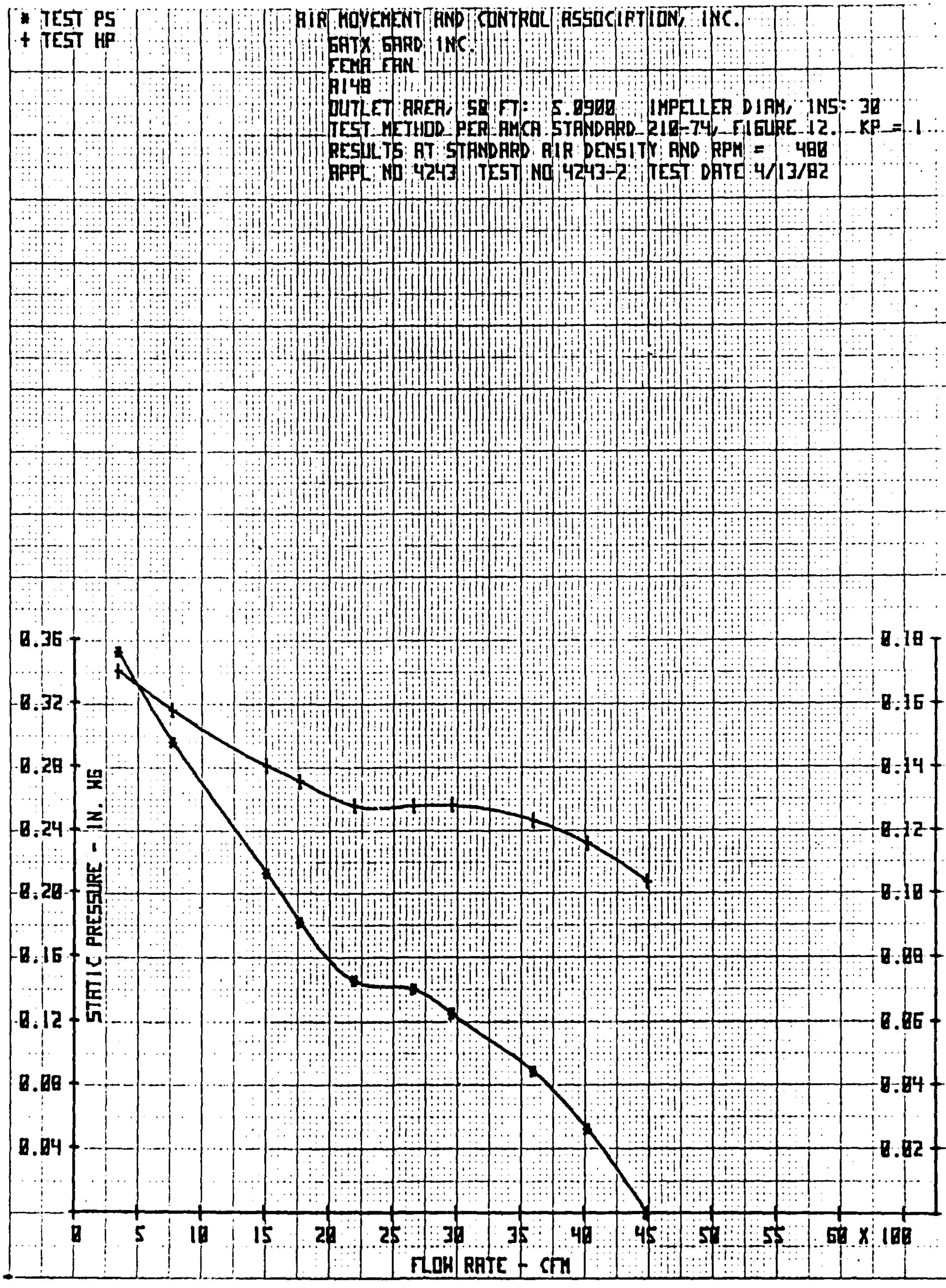
TEST METHOD PER AMCA STANDARD 210-74, FIGURE 12. CALCULATIONS BASED ON INCOMPRESSIBLE FLOW CONDITIONS (KP>0.99). KP = 1 USED THROUGHOUT.
REMARKS: CONTRACT (STEEL WHEEL, 20 DEG. BLADE)

RESULTS AT TEST CONDITIONS:

DET	PB	DENSITY	RPM	PT	PV	PS	CFM	HP	%NT	%NS
1	29.148	0.07196	482	0.047	0.047	0.000	4507.9	0.100	33.17	0.00
2	29.148	0.07196	482	0.088	0.038	0.050	4034.8	0.112	49.48	28.2[illegible]
3	29.148	0.07198	482	0.115	0.030	0.085	3607.4	0.119	54.61	40.33
4	29.148	0.07198	482	0.140	0.020	0.120	2970.5	0.124	52.75	45.08
5	29.148	0.07215	482	0.151	0.016	0.135	2667.9	0.124	51.12	45.5[illegible]
6	29.148	0.07215	482	0.151	0.011	0.140	2202.9	0.124	42.14	39.01
7	29.148	0.07201	482	0.182	0.007	0.175	1774.2	0.131	38.67	37.13
8	29.148	0.07201	482	0.210	0.005	0.205	1509.6	0.136	36.63	35.7[illegible]
9	29.148	0.07191	482	0.286	0.001	0.285	771.2	0.153	22.69	22.59
10	29.148	0.07191	482	0.340	0.000	0.340	341.9	0.165	11.0[illegible]	11.08

RESULTS AT STANDARD FAN AIR DENSITY AND RPM = 480

DET	PT	PV	PS	CFM	HP	%NT	%NS
1	0.049	0.049	0.000	4489.1	0.103	33.17	0.00
2	0.091	0.039	0.052	4018.0	0.116	49.48	28.23
3	0.119	0.031	0.088	3592.4	0.123	54.61	40.33
4	0.145	0.021	0.124	2958.1	0.128	52.75	45.08
5	0.156	0.017	0.139	2656.9	0.128	51.12	45.55
6	0.156	0.012	0.144	2193.8	0.128	42.14	39.01
7	0.188	0.008	0.181	1766.8	0.135	38.67	37.13
8	0.217	0.005	0.212	1503.3	0.140	36.63	35.71
9	0.296	0.001	0.295	768.0	0.158	22.69	22.59
10	0.352	0.000	0.352	340.5	0.170	11.09	11.08



TEST NO. 4243-2, STEEL FAN - 20° BLADE PITCH

AIR MOVEMENT & CONTROL ASSOCIATION, INC. - TEST LABORATORY

```
00 DATA 0,0,1,0,480
01 DATA 1,0.83317,0.83317,0,3.28,481,72.8,72.8,73.4,60.6,29.3,72.2,180
02 DATA 2,0.045,2.62,481,72.8,72.8,73.4,60.6,29.3,72.2,200
03 DATA 3,0.1,1.81,482,72.8,72.8,72.6,60.2,29.3,72.2,225
04 DATA 4,0.12,1.45,482,72.8,72.8,72.6,60.2,29.3,72.2,230
05 DATA 5,0.13,1.035,482,72.9,72.9,73.3,60.7,29.3,72.2,230
06 DATA 6,0.16,0.645,482,72.9,72.9,74.1,61.1,29.3,72.2,235
07 DATA 7,0.215,0.3,482,72.9,72.9,74.1,61.1,29.3,72.2,245
08 DATA 8,0.255,0.13,482,72.8,72.8,74.8,61.6,29.3,72.1,260
09 DATA 9,0.31,0.025,482,72.8,72.8,74.8,61.6,29.3,72.1,280
```

AIR MOVEMENT & CONTROL ASSOCIATION, INC.

APPLICATION NO. 4243
TEST NO. 4243-3
DATE OF TEST 4/13/82

TEST UNIT:
MANUFACTURER: GATX GARD INC.
TRADE NAME: FEMA FAN
MODEL NO: A148
IMPELLER DIAM, INS: 30
OUTLET AREA, SQ FT: 5.0900

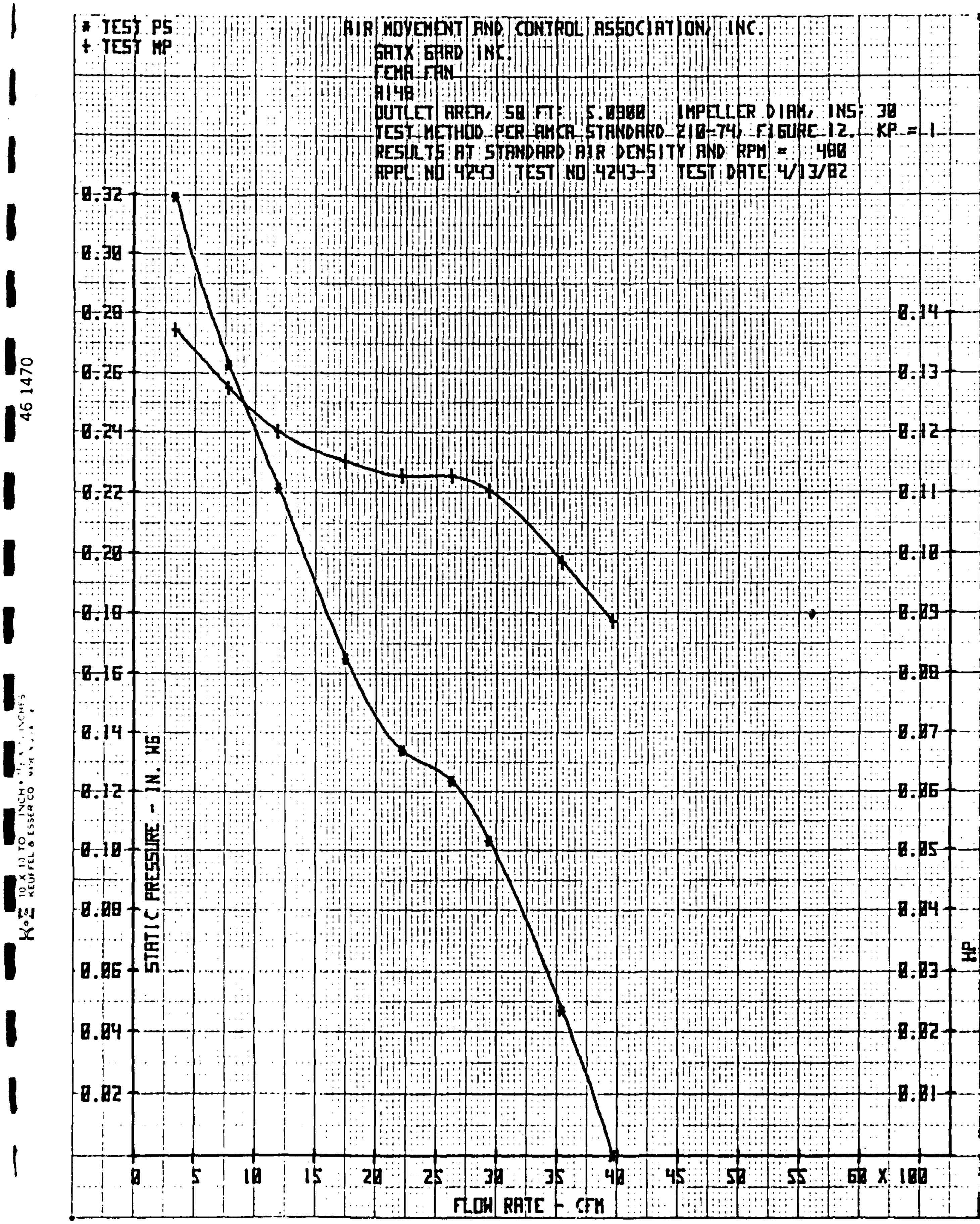
TEST METHOD PER AMCA STANDARD 210-74, FIGURE 12. CALCULATIONS BASED ON INCOMPRESSIBLE FLOW CONDITIONS (KP>0.99). KP = 1 USED THROUGHOUT.
REMARKS: CONTRACT(PLASTIC WHEEL, 20 DEG. BLADE)

RESULTS AT TEST CONDITIONS:

DET	PB	DENSITY	RPM	PT	PV	PS	CFM	HP	%NT	%NS
1	29.175	0.07226	481	0.037	0.037	0.000	3966.4	0.086	26.53	0.00
2	29.175	0.07226	481	0.074	0.029	0.045	3546.4	0.095	43.36	26.2
3	29.175	0.07227	482	0.120	0.020	0.100	2948.2	0.108	51.78	43.09
4	29.175	0.07227	482	0.136	0.016	0.120	2638.5	0.110	51.37	45.27
5	29.175	0.07225	482	0.142	0.012	0.130	2228.6	0.110	45.10	41.4
6	29.175	0.07224	482	0.167	0.007	0.160	1757.7	0.112	41.12	39.35
7	29.175	0.07224	482	0.218	0.003	0.215	1196.1	0.117	35.05	34.52
8	29.175	0.07225	482	0.256	0.001	0.255	784.7	0.124	25.45	25.3
9	29.175	0.07225	482	0.310	0.000	0.310	341.1	0.134	12.43	1[illegible].42

RESULTS AT STANDARD FAN AIR DENSITY AND RPM = 480

DET	PT	PV	PS	CFM	HP	%NT	%NS
1	0.038	0.038	0.000	3958.2	0.089	26.53	0.00
2	0.077	0.030	0.047	3539.0	0.098	43.36	26.29
3	0.124	0.021	0.103	2936.0	0.110	51.78	43.09
4	0.140	0.017	0.124	2627.6	0.113	51.37	45.27
5	0.146	0.012	0.134	2219.3	0.113	45.10	41.42
6	0.172	0.007	0.165	1750.4	0.115	41.12	39.35
7	0.225	0.003	0.221	1191.1	0.120	35.05	34.52
8	0.264	0.001	0.263	781.5	0.127	25.45	25.31
9	0.319	0.000	0.319	339.7	0.137	12.43	12.42



TEST NO. 4243-3, PLASTIC FAN - 20° BLADE PITCH

APPENDIX C

ENVIRONMENTAL TESTING OF A 30 INCH DIAMETER PLASTIC FAN BY GAYNES TESTING LABORATORIES, INC.

TEST REPORT

GARD, INC.
DIVISION OF GATX
NILES, ILL.

ENVIRONMENTAL TESTING OF A

30 INCH PLASTIC FAN

Test Conducted By: Richard E. Muir
Richard D. Hubbard
for

JOB No. 82336

ORDER No. H26364

DATE 15 May to 21 May 1982

GAYNES

TESTING LABORATORIES, INC.

1642–52 West Fulton Street • Chicago, Illinois 60612 • Area Code 312/421-52

Member: American Council of Independent Laboratories

ENVIRONMENTAL TESTS - FAN BLADE ASSEMBLY

TEST OBJECTIVE:

The objective of the test is to subject one (1) fan blade assembly to a series of high temperature and low temperature tests. These tests are designed to simulate potential storage and service conditions for the fan blade.

TEST PRODUCT:

The fan balde to be tested consists of four (4) polypropylene (30% glass filled) blades mechanically attached to an aluminum hub with rivets. The tip diameter of the fan assembly is 30 inches. The individual blade curvature (pitch) is 27°.

TEST PROCEDURE:

Prior to placement inside the test chamber, each of the four plastic blades will be checked for blade curvature and straightness using a steel blade supplied by GARD as an inspection gage tool.

At the end of each test sequence the blades will be rechecked with the gage tool to assure no warpage has occurred. In addition, a visual inspection of each blade will be performed to detect possible fractures or structural degradation.

Procedure No. 1 - High Temperature

A. Temperature maintained at 60°C (140°F) - 48 hrs. - Low Relative Humidity.
B. Temperature reduced to 110°F to stabilization of frames
C. Inspection
D. Temperature reduced to room ambient
E. Inspection & Measurement (using steel blade)

Procedure No. 2 - High Temperature Cycling

A. Temperature raised to 49°C (120°F) and held for 6 hours.
B. Temperature raised within 1 hour to 60°C (140°F) and held for 4 hours.
C. Temperature lowered with 1 hour to 49°C (120°F).
D. Repeat steps A, B & C for a total of 3 complete cycles.
E. Temperature reduced to 110°F to stabilization of frames.
F. Inspection.
G. Temperature reduced to room ambient.
H. Inspection & Measurement (using steel blade).

Procedure No. 3 - Low Temperature

A. Temperature reduced to -34°C (-30°F) and held for 24 hours.
B. Temperature raised to room ambient.
C. Inspection & Measurement (using steel blade).
D. Repeat steps A, B & C.

TEST RESULTS:

The fan assembly remained in the same relative condition at the end of each test procedure sequence and at the conclusion of the test. There was no apparent distortion, warpage or change in the components from a material standpoint or in relation to the overall assembly position when compared to the provided contour gage.

Upon completion of tests, the test sample was returned to Gard, Inc., for further inspection and evaluation.

Testing was started 14 May 1982 and completed 21 May 1982.

INSTRUMENTATION:

INSTRUMENT OR EQUIPMENT	MANUFACTURER	MODEL NO.	SERIAL NO.	CALIB. DATE
Temperature Chamber	Murphy & Miller	LTU-27	57384	4-12-82
Digital Thermometer	Fluke	2190A	A334	1-11-82
*Metal Blade	Torin	27"	None	
(Test Gage for Checking Sample Contours:)				

*Customer Furnished Test Equipment

GARD, INC., NILES, ILLINOIS

Fan Blade Development
GARD Final Report A1-48
FEMA Contract No. EMW-C-0600, FEMA Work Unit 1423G
By Buday, J. M.
September 1982 (UNCLASSIFIED) pp

The objective of the subject program was to develop an Improved Fan Blade that could be utilized in place of the current steel fan blade on the Pedal Ventilator Kit (PVK). The goals of the program were to reduce both the unit cost and weight of the fan while maintaining its effectiveness and reliability. A value analysis study was conducted on the fan blade to determine material/design revisions that offered potential manufacturing economics. Based on the conclusions of the study, two fan designs were constructed and tested. As a result of the testing, one fan emerged as the optimum design. Fifteen fan blades of the chosen design were constructed for FEMA inspection and distribution. Preliminary specifications and cost estimates based on a procurement of 100,000 units were formulated.

GARD, INC., NILES, ILLINOIS

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